DIVISIÓN DE RAYOS CÓSMICOS

smf®

SOCIEDAD MEXICANA DE FÍSICA

Simulations and Theory of the Effect of Atmospheric Electricity on Cosmic Rays

MSc Jania Newton
Tutor: Dr. Luis Xavier González

UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO

POR MI RAZA HABLARA EL ESPIRITU

Introduction

- Atmospheric electric fields (AEFs), generated by thunderstorms, influence the acceleration of charged particles.
    - They possibly produce a change in the intensity of the CR detected on the ground.
    - High-altitude observatories such as the Sierra Negra CR Observatory (SN-CRO), located at 4,580 m asl, will have a greater probability of observing the effect of AEFs.
- Objective:
    - Analyze the possible effect of AEFs on the CR detected by the Solar Neutron Telescope (TNS), installed at SN-CRO, Mexico.

Presentation Outline

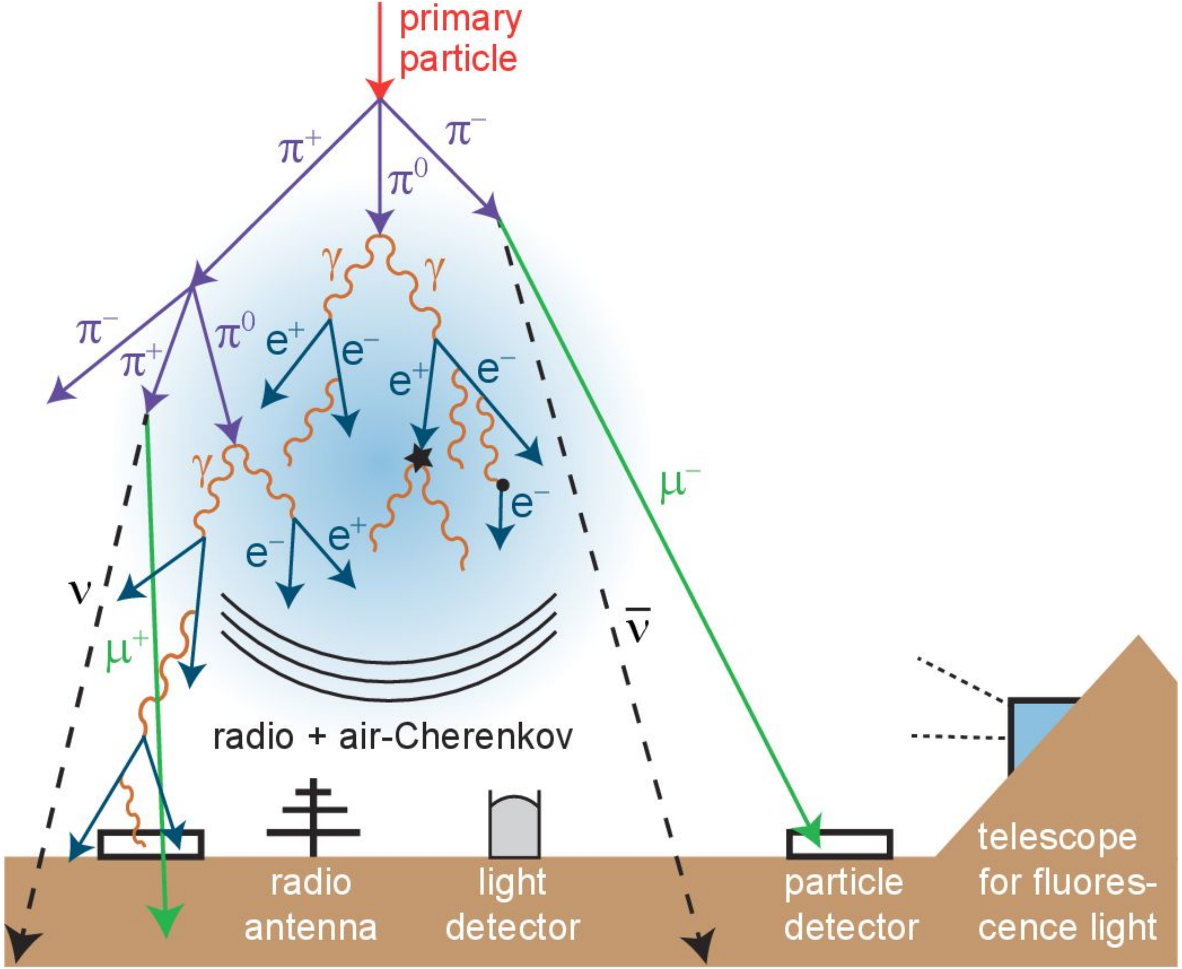
1. Effects of AEF on CR
2. Dorman’s General Theory
3. Simulations
4. Results & Discussion
5. Conclusions

Effects of AEF on CR

Cosmic Rays

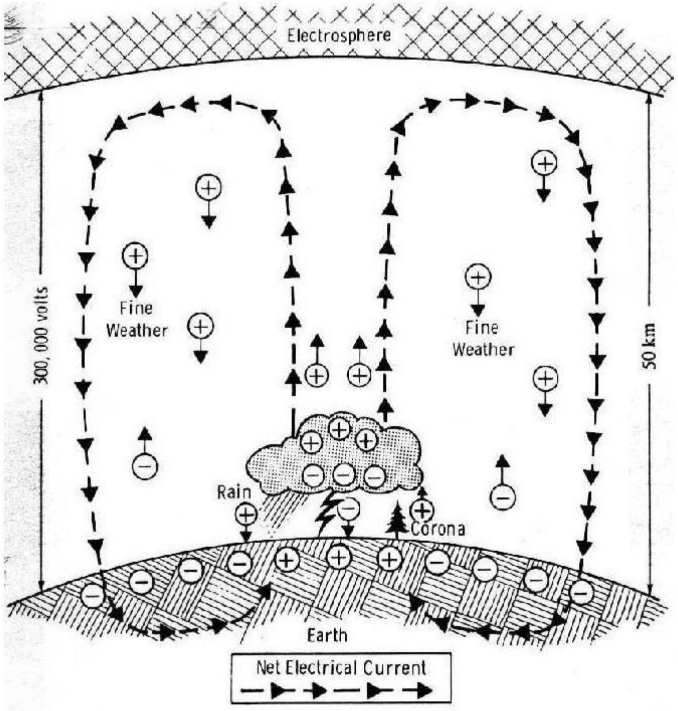
Taken from [1]

- CR constantly arrive on Earth from different sources in the Universe.
- They produce secondary particles in EAS.


primary particle
π+
π0
π−
γ
e+
e−
μ−
μ+
ν
ν̄
radio + air-Cherenkov
radio antenna
light detector
particle detector
telescope for fluores-cence light

Taken from [2]

Atmospheric Electric Fields

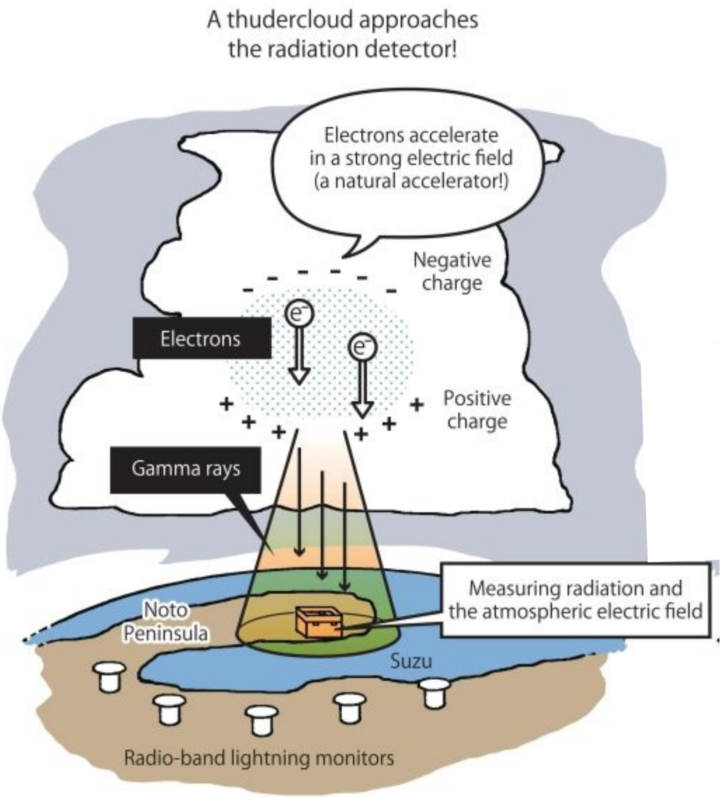


Muon Mechanism

Taken from [3]

- The variation of AEFs entails the decrease in the intensity of muons.
- Scintillator plastic detectors (E ~ 100 MeV) observe decreases during thunderstorms.

Electron Mechanism (Runaway electron avalanche)



Taken from [4]

Dorman's General Theory

- The intensity of any secondary CR component of type *i*, may be described by equation:

$$I_i(h_o, R_c, g, T(h), e(h), \mathbf{E}(h)) = \int_{R_c}^{\infty} D(R) m_i(h_o, R, g, T(h), e(h), \mathbf{E}(h)) dR$$

Assuming:

$$\Delta\mathbf{E}(h) = \mathbf{E}(h) - \mathbf{E}_o(h)$$

$$\Rightarrow \left(\frac{\Delta I_i(h_o, R_c, g_o, T_o(h), e_o(h), \mathbf{E}(h))}{I_i(h_o, R_c, g_o, T_o(h), e_o(h), \mathbf{E}_o(h))} \right)_E = \int_0^{h_o} W_{iE}(h, h_o, R_c) \Delta\mathbf{E}(h) dh \qquad \ldots (1)$$

Where the AEF coefficient is:

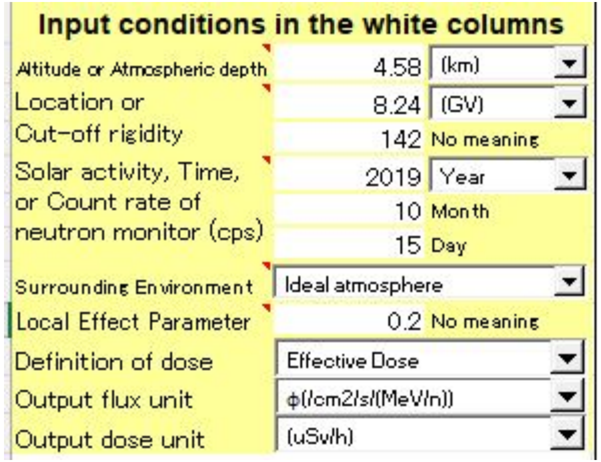
$$W_{iE}(h,h_o,R_c) = \int_{R_c}^{\infty} \frac{\delta m_i(h_o,R,g_o,T_o(h),e_o(h),\mathbf{E}(h))}{m_i(h_o,R,g_o,T_o(h),e_o(h),\mathbf{E}_o(h))\delta\mathbf{E}(h)} W_{iR_c}(h_o,R,g_o,T_o(h),e_o(h),\mathbf{E}_o(h))dR$$

And the coupling function:

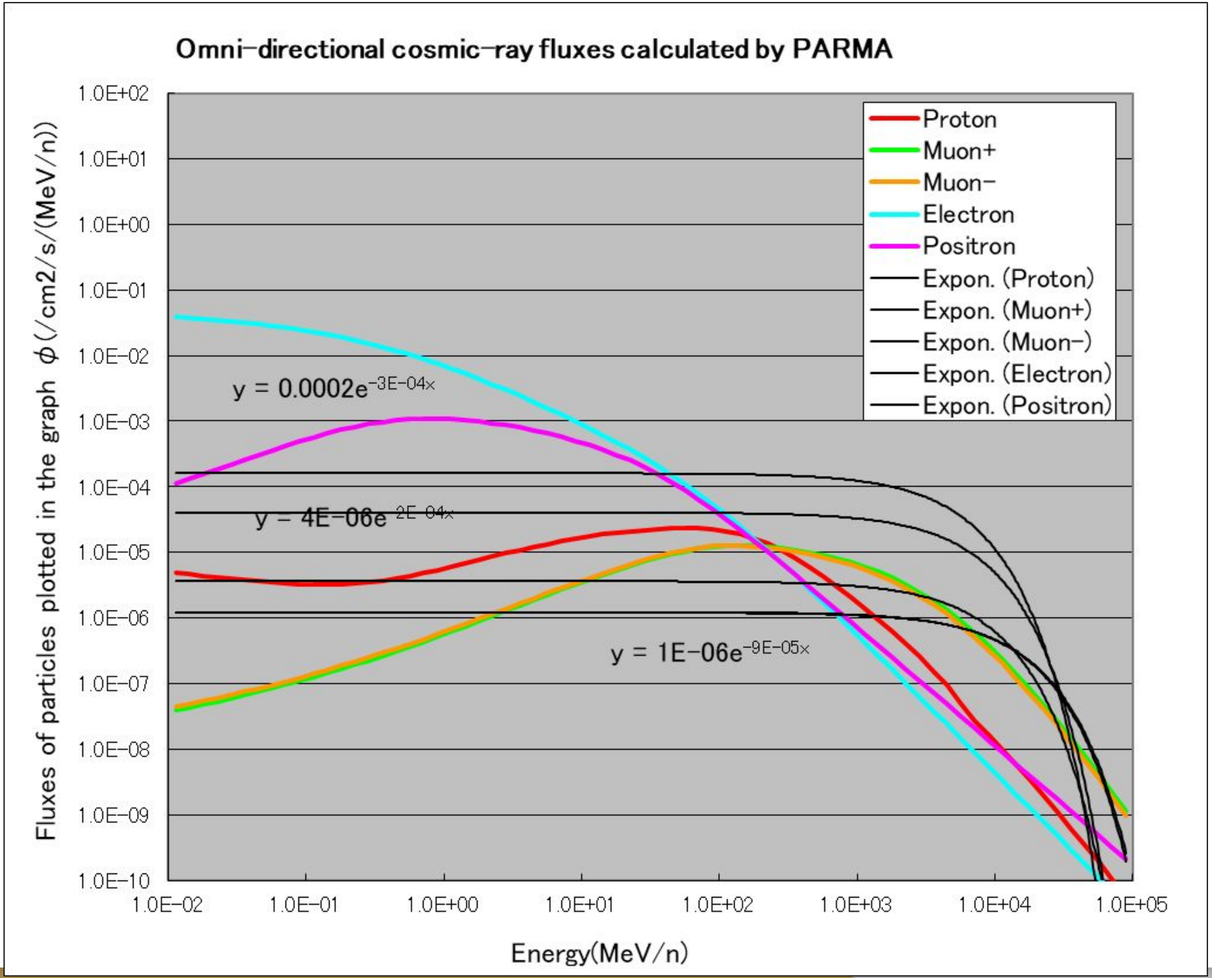
$$W_{iR_c}(h_o,R,g_o,T_o(h),e_o(h),\mathbf{E}_o(h)) = \frac{D_o(R)m_i(h_o,R,g_o,T_o(h),e_o(h),\mathbf{E}_o(h))}{I_i(h_o,R_c,g_o,T_o(h),e_o(h),\mathbf{E}_o(h))}$$

Simulations

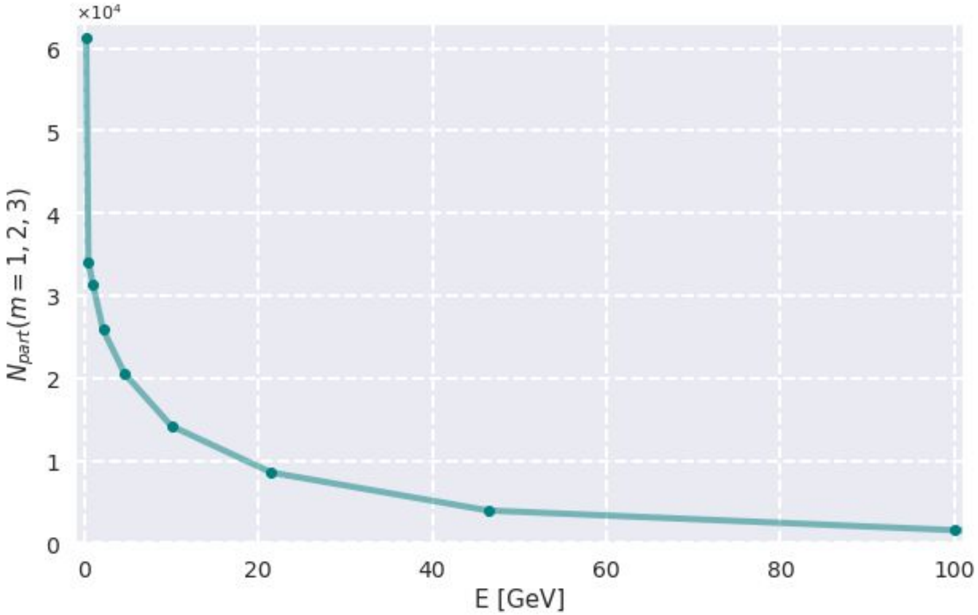
- EXPACS
  - Simulation of secondary RC flux.
  - The intensities of protons, muons, electrons and positrons were considered as the total charged component of secondary CR.
  - We fitted exponential functions to the flux of the charged particle component to find the coupling function.
- CORSIKA
  - Simulation of EAS.
  - The hadronic interactions for our simulations were modeled with QGSJET II-04 for high energies (above 80 GeV) and FLUktuierende KAskade (FLUKA) for low energies (below 80 GeV).
  - Simulation performed with and without a simple point dipole AEF.



EXPACS Results



CORSIKA Results



Solving Dorman's AEF coefficient equation

- We found an AEF coefficient for the total charged secondary CR component:

$$W_{iE}(h, h_0, R_c) \approx 2 \times 10^{-4}\ \%\ (kV/m)^{-1}(g/cm^2)^{-1}$$

- Finally, solving equation 1:

$$\left(\frac{\Delta I_i(h_o, R_c, g_o, T_o(h), e_o(h), \mathbf{E}(h))}{I_i(h_o, R_c, g_o, T_o(h), e_o(h), \mathbf{E}_o(h))}\right)_E = \int_0^{h_o} W_{iE}(h, h_o, R_c)\Delta\mathbf{E}(h)dh$$

With E(h) = 10 kV/m,E(h) = 20 kV/m and E(h) = 30 kV/m, the intensity variations for the total charged component were ±1.15%, ±2.32% and ±3.47%, respectively.

Conclusions

- Based on the EAS simulations performed with CORSIKA and EXPACS to solve the equations representing the AEF effect on CR flux proposed by Dorman, we conclude that the effect of AEF on secondary CRs is significant at the Sierra Negra altitude (4580 m a.s.l.).
- We found that for the total charged component of secondary CRs, the variation attributed to AEF is 1.15-3.47% at Sierra Negra.

Thank you!

References

[1] CERN. Cosmic rays: particles from outer space. Revisado el 20/07/2020. https://home.cern/science/physics/cosmic-rays-particles-outer-space.

[2] Radio detection of Extensive Air Showers (ECRS 2016) https://www.semanticscholar.org/paper/Radio-detection-of-Extensive-Air-Showers-%28ECRS-Schroder/dcd064b9d9a93433180a847e809088571bf7e484/figure/0

[3] https://www.forbes.com/sites/startswithabang/2021/02/03/why-the-unexpected-muon-was-the-biggest-surprise-in-particle-physics-history/?sh=ba915a771519

[4] https://www.u-tokyo.ac.jp/focus/en/articles/z0508_00006.html